Response
Applicant: Hong-Jyh Li
Serial No.: 10/816,503
Filed: April 1, 2004
Docket No.: 2004P51130US/I331.128.101
Title: PLASMA ION IMPLANTATION SYSTEM

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REMARKS

The following remarks are made in response to the Non-Final Office Action mailed July 10, 2006. Claims 1-31 were rejected. Claims 1-31 remain pending in the application and are presented for reconsideration and allowance.

Claim Rejections under 35 U.S.C. § 103

The Examiner rejected claims 1-31 under 35 U.S.C. § 103(a) as being unpatentable over Collins et al., U.S. Patent Pub. No. 2004/0107909 ("Collins") in view of King et al., U.S. Patent No. 6,855,994 ("King"). The Examiner rejected claims 4, 8, 10, 11, 14, 16, 17, 20, 23, 25, 28, 30, and 31 under 35 U.S.C. § 103(a) as being unpatentable over Collins and King in view of Chan, U.S. Patent No. 5,449,920 ("Chan"). The Examiner admitted that the combination of Collins and King fails to teach an ion implantation apparatus having (a) a constant DC voltage source, as recited in claims 4, 8, 23, and 28; (b) acceleration of positive ions, as recited in claims 8, 10, 11, 14, 16, 17, 20, 25, and 30; and (c) ion energies, as recited in claim 31. (Office Action, pages 4-5). Since dependent claims 9-15, 17-24, and 26-31 further define independent claim 8, 16, or 25, Applicant assumes that all these dependent claims are also rejected under 35 U.S.C. § 103(a) as being unpatentable over Collins and King in view of Chan despite the Examiner only listing dependent claims 10, 11, 14, 17, 20, 23, 28, 30, and 31. Therefore, Applicant assumes that the rejection of claims 1-31 under 35 U.S.C. § 103(a) as being unpatentable over Collins and King only applies to claims 1-3 and 5-7. Applicant will address the rejections to the claims based on these assumptions.

The Examiner rejected claims 1-3 and 5-7 under 35 U.S.C. § 103(a) as being unpatentable over Collins and King.

Applicant submits that Collins and King, either alone, or in combination, fail to teach or suggest the invention recited by independent claim 1 including **a voltage source configured to provide a bias voltage between the sample holder and the vacuum chamber to attract ions to implant in a high-k dielectric layer of a sample positioned on the sample holder, wherein the high-k dielectric layer has a k value greater than 9.**

The Examiner admits that Collins fails to teach the use of a high-k dielectric layer having a k value greater than 9. The Examiner submits that King teaches this claim

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limitation. (Office Action, page 3). Applicant submits that King also fails to teach or suggest these claim limitations.

King discloses a semiconductor device including a gate oxide of multiple thicknesses for multiple transistors where the gate oxide thicknesses are altered through the growth process of implanted oxygen ions into selected regions of a substrate. (Abstract). King discloses that the process illustrated in FIGS. 1D-1E includes the deposition of a high dielectric constant layer at the silicon substrate surface prior to the deposition of the polysilicon gate 18. A suitable high dielectric constant layer can be silicon nitride, zirconium oxide, or hafnium silicate (HfSiO). Thereafter, oxygen implantation into the silicon substrate and/or polysilicon gate followed by annealing, as in the process of FIGS. 1D-1F, will grow a very thin (<2 nm) silicon oxide with well-controlled thickness. The thin oxide can serve as the buffer layer or interfacial layer that is critical to the attainment of high carrier mobility and low interface defects. (Col. 4, lines 25-36).

King fails to disclose a voltage source configured to attract ions to *implant in a high-k dielectric layer* of the sample as recited in claim 1. In contrast, King discloses oxygen implantation into the *silicon substrate and/or polysilicon gate*. The oxygen is not implanted into the high dielectric constant layer.

In view of the above, Applicant respectfully submits that the above rejection of claim 1 under 35 U.S.C. § 103(a) should be withdrawn. Dependent claims 2, 3, and 5-7 further define patentably distinct independent claim 1. Accordingly, Applicant believes these dependent claims are also allowable over the cited references. Allowance of claims 1-3 and 5-7 is respectfully requested.

The Examiner rejected claims 4 and 8-31 under 35 U.S.C. § 103(a) as being unpatentable over Collins and King in view of Chan.

Dependent claim 4 further defines patentably distinct independent claim 1. Accordingly, Applicant believes this dependent claim is also allowable over the cited references. Allowance of claim 4 is respectfully requested.

In addition, there is no teaching or suggestion to combine Collins, King, and Chan to arrive at the invention recited by claim 4. In fact, Collins and Chan teach away from such a combination.

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Collins is directed to a plasma immersion ion implantation process. Collins discloses that one type of plasma immersion ion implantation reactor employs a pulsed D.C. voltage applied to a pedestal supporting the semiconductor wafer in a vacuum chamber filled with a dopant-containing gas such as BF3. Collins states that such a reactor is unacceptably sensitive to changes in the condition of the chamber surfaces, for example, to contamination of the chamber surfaces. As a result, such a plasma ion immersion implantation reactor cannot maintain a target junction depth or abruptness, for example, and is plagued by contamination problems. (Para. 0008).

Collins states that one problem inherent with D.C. voltage applied to the wafer support is that its pulse width must be such that the dopant ions are accelerated across the plasma sheath near the wafer surface with sufficient energy to reach the desired junction depth below the surface, while the pulse width must be limited to avoid (discharge) any charge build-up on the wafer surface that would cause device damage (charging damage). The limited pulse width is problematic in that the periodic decrease in ion energy can result in the deposition on the semiconductor surface rather than implantation, the deposition accumulating in a new layer that can block implantation during the pulse on times. Another problem arises because ions must impact the wafer surface with at least a certain target energy in order to penetrate the surface up to a desirable depth (the as-implanted junction depth) and become substitutional below the surface and up to the desired annealed junction depth during the annealing process. Below this energy, they do not penetrate the surface up to the as-implanted junction depth and do not become substitutional at the desired junction depth upon annealing. Moreover, the ions below the target energy may simply be deposited on the wafer surface, rather than being implanted, to provide a film that can impede implantation. Unfortunately, due to resistive and capacitive charging effects (RC time constant) on dielectric films on the wafer that tend to accompany a D.C. discharge, the ions reach the target energy during only a fraction of each pulse period (e.g., during the first microsecond), so that there is an inherent inefficiency. Moreover, the resulting spread in ion energy reduces the abruptness of the P-N junction. This problem cannot be solved by simply increasing the bias voltage, since this would increase the junction depth beyond the desired junction depth. (Para. 0010).

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In addition, Collins states that another type of plasma ion immersion implantation reactor employs a microwave power applicator for generating the plasma. This reactor has a microwave waveguide pointed axially downward to a magnetic field centered about the axis. Electron cyclotron resonance (ECR) occurs in a particular surface of the field to produce the plasma (for a microwave frequency of 2.45 GHz, this surface is where the magnetic field is about 875 gauss). The magnetic field is divergent, with a field gradient creating a drift current towards the substrate being processed. This drift current consists of both electrons (directly acted on by the interaction of microwave induced electric field and divergent DC magnetic field) and positively-charged ions (indirectly acted on by the deficit in negative charge formed due to the out-flux of electrons) and corresponding to a voltage of 10 to 100 eV. One problem is that the magnetic field gradient is non-uniform, so that the radial distribution of plasma ion energy is non-uniform, causing non-uniform junction depth across the wafer. Another problem is the relatively high ion energy directed at the wafer, limiting the degree to which junction depths can be minimized. Another way of addressing the non-uniformity issues is to place another magnet array between the source and the wafer, in an effort to straighten the magnetic field. However, the additional magnetic field would increase magnetic flux at the wafer surface, increasing the risk of charge damage to semiconductor structures on the wafer. (Para. 0013).

In summary Collins states plasma immersion ion implantation reactors have various limitations, depending upon the type of reactor: plasma reactors in which a pulsed D.C. voltage is applied to the wafer pedestal are too sensitive to chamber conditions and are inefficient; and plasma reactors with microwave ECR sources tend to produce non-uniform results. (Para. 0014).

Chan is directed to a large area ion implantation apparatus that selects ions having predetermined characteristics for implantation. The ions having predetermined characteristics are selected from a plasma contained within a magnetic bottle and heated by a radio frequency source. (Abstract). The wafer holder 110 is connected to a negative constant DC or pulsed bias voltage source 122 that biases the wafer 115 to a predefined negative potential. The bias potential applied to the wafer holder 110 contributes to the implantation energy of the ions. (Col. 5, line 63 – Col. 6, line 2).

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Chan states that a method used for large wafer ion implantation is termed plasma immersion. In this method, a wafer is positioned within a plasma and is pulse biased to a highly negative voltage. The ions of the plasma bombard the wafer and are implanted. The problem associated with this method is that the ions of the plasma that bombard the wafer have a distribution of energies and as a result the ions that are implanted penetrate into the wafer to various depths. This results in a non-uniform implantation layer. Furthermore, this method has no control over the composition of the ion species implanted since all of the positive ion species in the plasma will be implanted. (Col. 1, lines 21-33).

As indicated by the above cited text of Collins and Chan, Collins and Chan teach away from combining the plasma immersion ion implantation process of Collins with the negative constant DC or pulsed bias voltage source 122 of the implantation apparatus of Chan to arrive at the invention recited by claim 4. Collins, in great length, discusses the problems associated with an implantation apparatus using magnetic fields such as that disclosed by Chan and an implantation apparatus using a D.C. voltage applied to the wafer pedestal. Therefore, one skilled in the art would not combine the D.C. voltage source disclosed by Chan with the implantation apparatus of Collins and arrive at the invention recited by claim 4.

For the same reasons as discussed above with reference to claims 1 and 4, Collins, King, and Chan, either alone, or in combination, also fail to teach or suggest the invention recited by independent claim 8 including **a constant DC voltage source configured to accelerate positive ions toward a high-k dielectric layer of the sample to implant the positive ions in the high-k dielectric layer and to repel negative ions from the sample, wherein the high-k dielectric layer has a k value greater than 9.**

In view of the above, Applicant respectfully submits that the above rejection of claim 8 under 35 U.S.C. § 103(a) should be withdrawn. Dependent claims 9-15 further define patentably distinct independent claim 8. Accordingly, Applicant believes these dependent claims are also allowable over the cited references. Allowance of claims 8-15 is respectfully requested.

In addition, it appears that the Examiner has failed to directly address all the limitations of claims 13-15. Applicant respectfully submits that Collins, King, and Chan, either alone, or in combination, fail to teach or suggest the further limitations of **wherein the sample comprises a buffer layer proximate the high-k dielectric layer** (claim 13),

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wherein the DC voltage source is configured to accelerate positive ions toward the buffer layer of the sample to implant the positive ions in the buffer layer (claim 14), and **wherein the buffer layer comprises one of TiN, HfN, TaN, ZrN, LaN, SiN, and TiSi** (claim 15).

For the same reasons as discussed above with reference to claims 1 and 4, Collins, King, and Chan, either alone, or in combination, also fail to teach or suggest the invention recited by independent claim 16 including **a voltage source configured to accelerate positive ions toward a first high-k dielectric layer of the sample to implant the positive ions in the first high-k dielectric layer and to repel negative ions from the sample, wherein the first high-k dielectric layer has a k value greater than 9.**

In view of the above, Applicant respectfully submits that the above rejection of claim 16 under 35 U.S.C. § 103(a) should be withdrawn. Dependent claims 17-24 further define patentably distinct independent claim 16. Accordingly, Applicant believes these dependent claims are also allowable over the cited references. Allowance of claims 16-24 is respectfully requested.

In addition, it appears that the Examiner has failed to directly address all the limitations of claims 17 and 19-22. Applicant respectfully submits that Collins, King, and Chan, either alone, or in combination, fail to teach or suggest the further limitations of **wherein the voltage source is configured to accelerate positive ions toward a second high-k dielectric layer of the sample adjacent the first high-k dielectric layer to implant the positive ions in the second high-k dielectric layer** (claim 17), **wherein the second high-k dielectric layer comprises one of HfO_2, $HfSiO_x$, ZrO_2, $ZrSiO_x$, Ta_2O_5, La_2O_3, and AL_2O_3** (claim 19), **wherein the voltage source is configured to accelerate positive ions toward a buffer layer of the sample adjacent the second high-k dielectric layer to implant the positive ions in the buffer layer** (claim 20), **wherein the buffer layer comprises at least one of TiN, HfN, TaN, ZrN, LaN, SiN, and TiSi** (claim 21), and **wherein the buffer layer comprises a stack of layers** (claim 22).

For the same reasons as discussed above with reference to claims 1 and 4, Collins, King, and Chan, either alone, or in combination, also fail to teach or suggest the invention recited by independent claim 25 including **positioning a sample comprising a high-k dielectric layer on a sample holder in a vacuum chamber, the high-k dielectric layer**

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having a k value greater than 9; and accelerating positive ions in the plasma toward the sample to implant the positive ions in the high-k dielectric layer while repelling negative ions from the sample.

In view of the above, Applicant respectfully submits that the above rejection of claim 25 under 35 U.S.C. § 103(a) should be withdrawn. Dependent claims 26-31 further define patentably distinct independent claim 25. Accordingly, Applicant believes these dependent claims are also allowable over the cited references. Allowance of claims 25-31 is respectfully requested.

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CONCLUSION

In view of the above, Applicant respectfully submits that pending claims 1-31 are in form for allowance and are not taught or suggested by the cited references. Therefore, reconsideration and withdrawal of the rejections and allowance of claims 1-31 is respectfully requested.

No fees are required under 37 C.F.R. 1.16(b)(c). However, if such fees are required, the Patent Office is hereby authorized to charge Deposit Account No. 50-0471.

The Examiner is invited to contact the Applicant's representative at the below-listed telephone numbers to facilitate prosecution of this application.

Any inquiry regarding this Amendment and Response should be directed to Steven E. Dicke at Telephone No. (612) 573-2002, Facsimile No. (612) 573-2005. In addition, all correspondence should continue to be directed to the following address:

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CERTIFICATE UNDER 37 C.F.R. 1.8:

The undersigned hereby certifies that this paper or papers, as described herein, are being transmitted via facsimile to Facsimile No. (571) 273-8300 on this 10th day of October, 2006.

By: Mark Peterson
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